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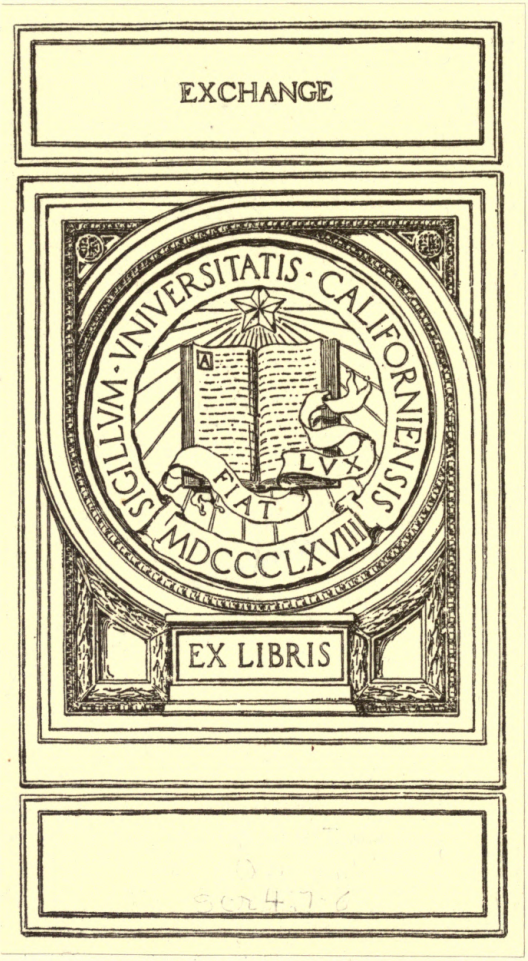

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GEOLOGICAL SURVEY OF OHIO

EDWARD ORTON, JR., State Geologist

FOURTH SERIES, BULLETIN No. 8.

SALT DEPOSITS

AND THE SALT INDUSTRY IN OHIO

BY

JOHN ADAMS BOWNOCKER, D. Sc.,

Professor of Inorganic Geology, Ohio State University.

Published by Authority of the Legislature of Ohio, Under the Supervision of the State Geologist.

COLUMBUS, OHIO, JUNE, 1906.

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Printed by the Springfield Publishing Company,
Springfield, Ohio.

LETTER OF TRANSMITTAL.

To His Excellency, JOHN M. PATTISON, *Governor of Ohio:*

SIR:—I have the honor to present to you herewith, the eighth bulletin of the fourth series of the publications of the Geological Survey of Ohio. The subject of the bulletin is the "Salt Deposits and the Salt Industry in Ohio," and it has been prepared by Professor John A. Bownocker, B. Sc., Professor of Geology in the Ohio State University. This subject was made the basis of a chapter by Willis T. Root, E. M., in Volume VI, published in 1888. The reason for again reporting upon it is that the old industry existing at that time is now practically extinct and a new industry on a wholly different basis has since sprung up. The new industry promises to become a very important one, and for that reason this report has been authorized and prepared. In my opinion, the subject has been well handled and will set forth what is now available on this subject in a useful way.

I have the honor to be,

Yours very respectfully,

EDWARD ORTON, JR., E. M.,
State Geologist.

Ohio State University.
June, 1906.

OFFICERS OF THE SURVEY.

EDWARD ORTON, Jr., E. M., ... State Geologist

CHARLES SMITH PROSSER, D. Sc ..... Assistant Geologist
Areal and Stratigraphical Geology.

JOHN ADAMS BOWNOCKER, D. Sc ..... Assistant Geologist
Economic Geology.

NATHANIEL WRIGHT LORD, E. M ..... Consulting Chemist
Constitution and Utilization of Coals.

METTA L. SEYMOUR ..... Stenographer and Clerk

ANNOUNCEMENTS BY THE STATE GEOLOGIST.

BULLETIN 8.

This bulletin has been prepared in response to a number of calls for exact information on the subject of the new rock salt discoveries in northeastern Ohio. The excellent work done by Mr. W. J. Root in 1888 on the salt industry as it then existed made it seem improbable that the subject would require reconsideration in the future. But geology is full of surprises of this sort. The drill brought to light in 1884 the existence of oil and gas underneath the level prairies of northwestern Ohio, a region where no geologist would have dared to prophesy the least encouragement for such resources. And similarly, the drill in northeastern Ohio has found large deposits of rock salt where an orderly sequence of shales, sandstones and limestones was expected. True, there is good geological precedent for the existence of these salt beds, and now that we know that they are there, it seems quite a matter of course that it should be so, but, the fact remains that geology did not lead any one to predict their discovery, which was due to search for oil and gas.

The discovery of this rock salt came at a time when the old industry, which had flourished since the days of the pioneers, was in the last stages of decadence. This industry, founded on the weak superficial brines of the coal-measures, which were often discovered from the "salt-licks" of the deer and buffalo, had been of the greatest importance and service to the settlers in early times, when all salt was almost a luxury and when it was generally carried over the mountains on horseback or in wagon trains. The discovery and manufacture of native salt in Ohio played a considerable part in the development of the state.

But, in the course of events, the discoveries of rock salt in Michigan, and the production of saturated brines instead of the weak brines of Ohio, soon gave that state an advantage which Ohio manufacturers could not meet. The cheap fuel of Michigan was also in her favor—the slabs and dust from the saw-mills gave a good combustible of which they were actually anxious to get rid. Michigan salt began crowding Ohio salt to the wall in the 70's and in 1890 there remained but a few plants still struggling along.

The revival of this industry on its present apparently permanent basis means much to Ohio. It means not only that we shall preserve

our position or improve it, in the industrial competition, but also that allied industries also may thrive—for instance, the manufacture of soda-ash, the manufacture of glass and soap and many other industries using the element sodium in some of its saline forms.

Professor Bownocker has pursued this study with diligence in the summers of 1904 and 1905 and has presented the facts in a clear, succinct manner which the practical men will enjoy, as well as those whose interests are more on the technical side.

FORMER PUBLICATIONS OF THE SURVEY.

The work performed by the First, Second and Third organizations of the Geological Survey of Ohio is comprehended in the following list of publications:

FIRST GEOLOGICAL SURVEY 1837-1838

Title of Volume.	Date of Issue.	Number of Pages.	Number of Copies Printed.	Geologist in Charge.
First Annual Report.....	1838	134	5,000	W. W. Mather
Second Annual Report.....	1838	236	5,000	W. W. Mather

SECOND GEOLOGICAL SURVEY 1869-1888.

Title of Volume.	Date of Issue.	Number of Pages.	Number of Copies Printed.	Geologist in Charge.
Report of Progress.....	1869	176	14,500	J. S. Newberry
Report of Progress.....	1870	568	14,500	J. S. Newberry
Report of Progress.....	1871	3	400	J. S. Newberry
Geology of Ohio, vol. I, part I, Geology.....	1872	680	20,000	J. S. Newberry
Geology of Ohio, vol. I, part II, Paleontology	1873	*401 †49	20,000	J. S. Newberry
Geology, of Ohio, vol. II, part I, Geology.....	1874	701	20,000	J. S. Newberry
Geology of Ohio, vol. II, part II, Paleontology	1875	*431 †59	20,000	J. S. Newberry
Geology of Ohio, vol. III, Geology	1878	958	20,000	J. S. Newberry
Geological Atlas of Ohio....	1879		5,000	J. S. Newberry
Geology of Ohio, vol. IV, Zoology and Botany.....	1882	1,070	20,000	J. S. Newberry
Geology of Ohio, vol. V, Economic Geology.....	1884	1,124	10,000	Edward Orton
Preliminary Report on Petroleum and Inflammable Gas	1886	76	2,500	Edward Orton
Geology of Ohio, vol. VI, Economic Geology.....	1888	831	15,000	Edward Orton

*Pages. †Plates.

THIRD GEOLOGICAL SURVEY 1889-1894.

Title of Volume.	Date of Issue.	Number of Pages.	Number of Copies Printed.	Geologist in Charge.
First Annual Report.....	1890	323	10,000	Edward Orton
Geology of Ohio, vol. VII, part I, Economic Geology.	1893	290	2,500	Edward Orton
Geology of Ohio, vol. VII, (complete including part I)	1894	970	7,500	Edward Orton

FOURTH GEOLOGICAL SURVEY 1899———

Title of Volume.	Date of Issue.	Number of Pages.	Number of Copies Printed.	Geologist in Charge.
Bulletin 1—Oil and Gas.....	1903	320	8,000	Edward Orton, Jr.
Bulletin 2—Uses of Cement..	1904	260	6,000	Edward Orton, Jr.
Bulletin 3 { Manufacture of Cements	1904	391	4,000	Edward Orton, Jr.
Bulletin 4 { Limestones and Lime.....	1906	365	4,000	Edward Orton, Jr.
Bulletin 5—Sand-Lime Brick	1906	79	4,000	Edward Orton, Jr.
Bulletin 6—Bibliography ...	1906	—*	3,500	Edward Orton, Jr.
Bulletin 7 { Nomenclature of Geological Formations....	1905	36	3,500	Edward Orton, Jr.
Bulletin 8 { Salt Deposits and Salt Industry	1906	42	3500	Edward Orton, Jr.

*In press.

DISTRIBUTION OF REPORTS.

First Geological Survey.—These volumes are out of print and rare. They can only be procured from dealers in second-hand libraries and are difficult to obtain even there.

Second Geological Survey.—These volumes were all distributed at the time of their issue. The State retained no stock for meeting future demands, so that no copies of any of these volumes can be obtained from the office of the State Geologist. They can be bought in many second-hand book stores, and from dealers in old libraries, at prices ranging from a few cents to two or three dollars per volume, according to rarity and demand. Volumes V and VI are the rarest and most sought for.

Third Geological Survey.—These volumes were all distributed at the time of issue, except Vol. VII, of which 1,500 were put in the hands of the Secretary of State, for sale at the cost of publication. Of these, a few remain at the date of the publication of this volume. The price is $1.50. To obtain copies, send postal or money order to the Secretary of State, State House, Columbus, Ohio. No other volumes can be obtained from this source.

The other volumes of this series can be procured only from second-hand book and library dealers.

Fourth Geological Survey.—Under the law, copies of these Bulletins can be bought at the office of the State Geologist at the cost of pub-

lication. Postal orders, money orders, checks, drafts, or currency must accompany orders. Stamps will not be received.

Bulletin 1—Oil and Gas.....$ 0.65
Bulletin 2—Uses of Hydraulic Cements..... 0.30
Bulletin 3—Manufacture of Hydraulic Cements..Issue exhausted.
Bulletin 4—Lime Resources and Lime Industries..In press.
Bulletin 5—Lime-Sand Brick Industry.....In press.
Bulletin 6—Bibliography of the Geology of Ohio, and Index to Publications of the Geological Survey of Ohio.....———
Bulletin 7—Revised Nomenclature of the Ohio Geological publications..... 0.06
Bulletin 8—Salt Deposits and Salt Industry in Ohio———

LAWS UNDER WHICH THE SURVEY OPERATES.

For the information of the public, the law under which the work of the Survey is prosecuted is herewith published:

Laws of Ohio, 1889, Vol. 86, p. 262.
(Senate Bill 409.)

AN ACT

To provide for the extension of the Geological Survey of the State.

Section 1. Be it enacted by the General Assembly of the State of Ohio, That the governor is hereby authorized to appoint a state geologist, whose duty it shall be to continue and extend the investigations already made into the geological structure and resources of the state. Said state geologist shall be appointed for a term of three years, but he may be removed for cause at any time, and a successor appointed in his stead; and the governor is authorized to fill any vacancy which may occur from any cause, at any time. The compensation of said state geologist shall be at the rate of two hundred dollars per month, for the time actually employed; and said geologist shall have power to employ such assistants as he may need; but in no event shall the salary of the geologist, pay of assistants, and expense of the department, exceed the amount of the expenditure authorized by the general assembly.

Section 2. It shall be the duty of said geologist to study, and determine as nearly as possible, the number and extent of the various formations of the state; to represent the same, from time to time, upon properly constructed maps and diagrams; to study the modes of occurrence and the distribution of the useful minerals and products of these formations; to determine the chemical composition and structure of the same; to investigate the soils and water supply of the state; and to give attention to the discoveries of coal, building stone, natural cement, petroleum, gas and other natural substances of use and value to the state. He may also collect and describe the fossils of the various geological formations of the state; but no expenditure shall be incurred under this head that is not expressly ordered and provided for by the general assembly.

Section 3. The said geologist shall make, on or before the first day in February of each year. a report to the governor, covering the work of the preceding year, and the report shall be transmitted to the general assembly, to be printed in the same manner as other public documents, or as shall be otherwise ordered.

Section 4. The salaries of the state geologist, and the assistants employed by him, together with the traveling and incidental expenses, shall be paid monthly, on presentation of properly itemized vouchers, signed by the governor, out of the state treasury, from the appropriation made for such purpose.

Section 5. There is hereby appropriated from the general revenue fund the sum of one thousand dollars annually, for the purpose above named.

Section 6. This act shall take effect and be in force from and after its passage.

NOAH H. ALBAUGH,
Speaker pro tem. of the House of Representatives.
THEODORE F. DAVIS,
President pro tem. of the Senate.

Passed April 12, 1889.

From the terms of the law, it was evidently intended to provide for the creation of a bureau of geology to which only a portion of the time of the State Geologist should be applied, as the annual appropriation made was much too small to provide the salary of a State Geologist continuously, without making any provisions for office expenses, assistance, etc. It was thought at that time that a few months' work per year would be sufficient to maintain the Survey abreast of geological developments.

The powers and duties of the State Geologist under this act were made so broad and general as to permit carrying on almost any work, so that no new legal provision was thought necessary in connection with re-opening the work of the Survey under the Fourth organization. The sum designated in Section 5 is not made a limiting condition of the law so that the Legislature may appropriate any other amount, at its discretion, for carrying on the work.

Acting under this law, the Legislature has made the following appropriations for geological work:

Designation of Legislature.	Year.	Amount Appropriated.
Seventy-Fourth.....	1900	$2,500 00
Seventy-Fourth.....	1901	$3,500 00
Seventy-Fifth.....	1902	$5,000 00
Seventy-Fifth.....	1903	$3,000 00
Seventy-Sixth.....	1904	$2,800 00
Seventy-Sixth.....	1905	$2,900 00
Seventy-Seventh	1906	$3,850 00*
Seventy Seventh	1907	$5,100 00

*And balance and receipts.

The law providing for the publication and distribution of reports is as follows:

Laws of Ohio, 1902, Vol. 95, p. 593.

(House Bill, 800).

AN ACT

To Provide for the Publication and Distribution of the Reports of the State Geologist.

Section 1. Be it enacted by the General Assembly of the state of Ohio, That whenever the state geologist shall have completed a bulletin upon any of the subjects

upon which he is authorized to conduct investigation, he shall notify the state printing commission of this fact, and it shall be the duty of this commission to determine the number of copies which shall be printed, and the grade of paper, the kind of binding, and any other details incident to its proper publication.

Section 2. It shall be the duty of said commission to provide for the publication of said bulletin as soon as possible after the completion of the same. The issue shall consist of a minimum number of three thousand copies.

Of these, one thousand copies, after deducting 200 for the State Library, shall be distributed pro rata among the general assembly.

One thousand shall be distributed free by the state geologist in exchange with other surveys, and with individuals whose services have been used in the collection or preparation of the matter for the bulletins. Of this number not more than four hundred may be distributed during the first year after publication, and not more than fifty in any subsequent year.

One thousand copies shall be set aside for binding along with other bulletins from time to time, when a sufficient number of such bulletins have accumulated to make collectively a volume of from 800 to 1,000 pages. They shall be bound, lettered and numbered, to take their place in the series of volumes already published by the survey.

The distribution of the bound volume of the survey shall be in the hands of the state geologist; but the state library shall receive ten copies, each member of the general assembly one copy, with privilege to draw not to exceed two other copies on application, and public libraries in the state shall be supplied with one copy each. The volumes remaining after these demands have been met, may be distributed among the geological surveys and geological societies of the United States and of foreign countries in exchange for their publications.

Section 3. The board may, at its discretion, order the publication of extra copies in addition to the three thousand already provided for. These extra copies shall be placed in the hands of the state geologist. From these members of the general assembly may, on application, draw up to fifty (50) copies each. Those remaining shall be placed on sale at a price equal to the net cost of printing and binding, which price is to be established by the state supervisor of public printing. The proceeds of such sales shall be accounted for and paid into the state treasury, and the state geologist shall be required by the commission to give suitable bond for the security of the funds thus passing through his hands. The proceeds of such sales shall be credited to the account of the geological survey and shall be used for the prosecution of the further work of the survey without distinction from other funds which the general assembly from time to time appropriates for the survey.

Section 4. The cost of printing, illustrating, electrotyping, binding, et cetera, of said bulletins and said volumes, shall be paid from the general appropriation for state printing.

Section 5. This act shall take effect from and after its passage.

W. S. McKINNON,
Speaker of the House of Representatives.
F. B. ARCHER,
President of the Senate.

Passed May 12, 1902.

THE SURVEY IN ITS RELATIONS TO THE PUBLIC.

The usefulness of the Survey is not limited to the preparation of formal reports in important topics. There is a constant and insistent desire on the part of the people to use it as a technical bureau for free advice in all matters affecting the geology or mineral industries of the State. A very considerable correspondence comes in, increasing rather than decreasing in amount, and asking specific and particular questions on points in local geology.

The volume of this correspondence has made it necessary to adopt a uniform method of dealing with these requests. Not all of them can be granted, but some can and should be answered. There is a certain element

of justice in the people demanding such information, from the fact that the geological reports issued in former years were not so distributed as to make them accessible to the average man or community today. The cases commonly covered by correspondence may be classified as follows:

1st. Requests for information covered by previous publications.—This is furnished where the time required for copying the answer is not too large. Where the portion desired cannot be copied, the enquirer is told in what volume and page it occurs and advised how to proceed to get access to a copy of the report.

2d. Requests for identification of minerals and fossils.—This is done, where possible. As a rule, the minerals and fossils are simple and familiar forms, which can be answered at once. In occasional cases, a critical knowledge is required and time for investigation is necessary. Each assistant is expected to co-operate with the State Geologist in answering inquiries concerning his field.

3d. Requests from private individuals for analyses of minerals and ores, and tests to establish their commercial value.—Such requests are frequent. They cannot be granted, however, except in rare instances. Such work should be sent to a commercial chemical laboratory. The position has been taken that the Geological Survey is in no sense a chemical laboratory and testing station, to which the people may turn for free analytical work. Whatever work of this sort is done, is done on the initiative of the Survey and not at the solicitation of an interested party.

The greatest misapprehension in the public mind regarding the Survey is on this point. Requests for State aid in determining the value of private mineral resources, ranging from an assay worth a dollar, up to drilling a test well costing several thousand dollars, represent extreme cases. At present there is no warrant for the Survey making private tests, even where the applicant is entirely willing to pay for the service. In many cases individuals would prefer the report of a State chemist or State geologist to that of any private expert, at equal cost, because of the prestige which such a report would carry. But it is a matter of doubt whether it will ever be the function of the Survey to enter into commercial work of this character; it certainly will not be unless explicit legal provisions for it are made.

4th. Requests from a number of persons representing a diversity of interests, who jointly ask the Survey to examine into and publicly report upon some matter of local public concern.—Such cases are not common. It is not always easy to determine whether such propositions are really actuated by public interest or not. Each case must be judged on its merits. The Survey will often be prevented from taking up such

investigations by the lack of available funds, while otherwise the work would be attempted.

The reputed discovery of gold is one of the most prolific sources of such calls for State examination. It usually seems wise and proper to spend a small sum in preventing an unfounded rumor from gaining acceptance in the public mind, before it leads to large losses, and unnecessary excitement. The duty of dispelling illusions of this sort cannot be considered an agreeable part of the work of the Survey, but it is nevertheless of very direct benefit to the people of the State.

SALT DEPOSITS AND THE SALT INDUSTRY IN OHIO

BY

JOHN ADAMS BOWNOCKER, D. Sc.

LETTER OF TRANSMITTAL

Professor Edward Orton, Jr., State Geologist:

DEAR SIR:—I transmit herewith my report on Salt Deposits and the Salt Industry in Ohio.

Respectfully submitted,

J. A. BOWNOCKER.

May 1st, 1906.

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Figure 1.—Map of Eastern Ohio.

SALT DEPOSITS AND THE SALT INDUSTRY IN OHIO.

I. INTRODUCTION

The first settlers of Ohio found salt one of the most expensive of necessities. At that time not a pound was produced in the territory, and in consequence residents were compelled to rely on the production east of the Appalachian mountains. The salt had to be transported on horseback or in wagons across the mountains, and hence was expensive. From 1788 to 1800 the price ranged from four to eight dollars per bushel,[1] and many residents felt that the absence of a local supply and the resulting high price would prove a serious handicap to the development of the country. When, however, the valleys of the southeastern part of the territory began to be explored, salt springs were found, and naturally the discoverers were not slow in taking advantage of these brines.

II. THE BEGINNING

Probably the first attempt to make salt on land now forming part of the state was in 1798.[2] The locality was the old Scioto salt works on the banks of Salt creek in what is now Jackson county. These salt springs were well known to the buffalo and other wild animals, long before the white man discovered them. Buffaloes came in herds, forming well beaten paths, recognizable as late at least as 1837.[3] Regular pilgrimages to the licks were made by these animals until they were driven from the territory. That they were loth to abandon so favored a spot is shown by the fact that the last buffalo seen native in Ohio was near these licks, the date being 1802.[4]

From earth works near the licks it has been thought that the Mound Builders appreciated the locality as well as did the lower animals. Later the spot was a favorite with the Indians; the men killed the game which came for brine, while their squaws busied themselves making a little salt. Wells were not dug, the Indians simply taking the brackish water from the creek at low water stage and evaporating it. The last of their old salt pans was blasted out in 1899.[5] Pilgrimages were made to the licks each summer by the Indians until about 1815.

The date of the white man's discovery of the licks is not known, but it was probably early in the eighteenth century by Canadian fur traders.

[1]The bushel contained at first 80 pounds; later 50 poun ds.
[2]*Am. Jour. Sci. and Arts*, vol. 24, p. 46.
[3]Whittesley quoted in *History of Jackson County, Ohio*. p. 11.
[4]Williams, *History of Jackson County, Ohio*. p. 14.
[5]Ibid, p. 31.

The Virginia colonists knew of them at least as early as 1755. In 1795 a company of white salt boilers settled on the licks, and the camp is said to have grown quite large before the close of the century.[1]

Officials of the federal government soon learned of the licks, and prompt action was taken to prevent their falling into the hands of parties who might make a monopoly of them. Thus in 1796 Congress passed an act providing for the sale of lands northwest of the Ohio river, but expressly reserved for future disposal the area containing these licks. No arrangement was made, however, for operating the licks, but this was done a few years later when the territory became a state.

Early wells at these licks were quite shallow, varying from 20 to 30 feet in depth. The brine was correspondingly weak, from 600 to 800 gallons being necessary to make a bushel of salt. The product had a dark color and was otherwise inferior, but it was so much better than none that it commanded a high price.

Other pioneer wells were located on Salt creek about nine miles southeast of Zanesville, on Duck creek in Noble and Washington counties, and in the valley of the Muskingum. In all of these the salt industry started near the beginning of the nineteenth century, probably about the time of the state's admission into the Union. It is worthy of mention in this connection that several of these wells demonstrated the presence of petroleum and natural gas, though advantage was not taken of the discovery.

April 30, 1802, Congress passed the enabling act preparatory to Ohio becoming a state, the act providing, among other things, that an area of 36 square miles containing the Scioto salt springs shall be granted to the state for the use of its inhabitants. The legislature was empowered to frame regulations governing the use of the licks. The whole object seems to have been to prevent individuals or companies from obtaining a monopoly of them.

The first state legislature met March 1st, 1803, and soon considered leasing the salt licks. An act became a law April 13, 1803, which provided:

(1) That the state shall keep an agent for one year at the licks, who shall issue license to salt makers, collect the rent, study the geology of the region, and in other ways look after the state's interests.

(2) That no person or company shall use more than 120 kettles.

(3) That persons making salt shall pay to the agent three cents per gallon, payable quarterly, on the capacity of the plant.

April 14, 1803, the two houses met together and elected James Denny agent as provided for in the act referred to above.

In January, 1804, a second act relating to the licks was passed. This described more specifically the lots that might be rented for salt purposes, fixed the rent at four cents per gallon, and required the agent to

[1]Ibid, p. 52.

inspect the salt. The rent was changed February 20th, 1805, to two cents per gallon; February 13, 1808, to one cent per gallon; and January 19, 1810, to one-half cent per gallon.

The quantity of salt produced did not meet the expectations of the legislators, and an act was passed February 17th, 1812, to encourage deeper drilling. Similar acts were passed in 1813, 1814, and 1815, the last requiring a depth of 350 feet. It is reported that the honest driller went 100 feet deeper than the law required. A stronger brine was found, but the quantity was not ample.

According to Hildreth, the region was at its zenith of activity from 1806 to 1808, when twenty furnaces were in action, each averaging from fifty to seventy bushels of salt per week. When stronger brines were found on the Kanawha and other localities the Scioto licks were at a disadvantage, the result being that the industry languished and was finally abandoned.

In 1818 the legislature announced that the salt licks were no longer a success, and asked Congress to permit the state to sell the land. This request was not granted until the closing days of 1824. In June, 1826, a three days' public sale was held and all lands not sold during that time were disposed of privately.

The act of Congress which provided that the Scioto salt licks should be reserved by the state also provided that where other licks were found, the enclosing land, 640 acres in area, should in a similar manner be retained by the state. Under this provision it appears that one tract was reserved on Salt creek in Muskingum county, and another one in Delaware county. These three localities were the only ones in Ohio known at that time where salt licks existed. These tracts also seem to have been disposed of by the state in 1826.[1]

It is said that as late as 1808 the wells penetrated the mantle rock only. The first effort to secure brine in bed rock is reported to have been made in the valley of the Great Kanawha, near Charleston. At first these wells reached depths ranging from 70 to 80 feet, but later extended to 350 feet. The brine was found to increase in strength with the depth, a discovery of great importance. In some places, however, deep wells were not a success, for example those of the Scioto salt licks.

In 1817 drilling began in the Muskingum valley, the first well having been located a few miles below Zanesville. Two years later a well was drilled in this town, water furnishing the power. These wells, however, seem never to have been profitable. Farther down the valley results were more favorable, wells existing at short intervals for a distance of 30 miles. Finding that the strength of brine increased with the depth, wells were drilled 850 feet deep, when a brine of such strength was found that a gallon made one pound of salt. By 1833 this valley is reported to have produced between 300,000 and 400,000 bushels per year.

[1] *Am. Jour. Sci. and Arts.*, vol. 24, p. 26.

Among other places producing considerable salt at about that time may be mentioned Yellow creek, Columbiana county, the valley of Hocking river in Athens county, and Leading creek, in Meigs county.

Drilling in those days was a laborious process. A hole from four to six feet in diameter was dug through the surface material into the bed rock. Into this hole, called the "head," was placed a hollow sycamore log known as the "gum," or in its stead a rectangular tube constructed of planks, to exclude surface water. At the lower end of this drilling began. In early years the spring pole was used, men furnishing the power. This was succeeded by the treadle, a horse doing the work. In still later years steam was used. During the first part of the century work continued as a rule day and night, the men working in shifts or tours of six hours each. Progress was very slow. It is stated that six feet were considered a large day's work. Caving was usually prevented by the insertion of a copper tube, though it does not appear that long strings of this tubing were used.

The salt was made by evaporating the brine in large iron kettles, each holding form 60 to 80 gallons. These were set in a row over a flue which terminated at one end in a chimney. The fuel was wood taken from the adjacent forests.

The brine was pumped from the wells into a tank constructed of wood, and connected by tubes made of the same material with the kettles. After having been boiled for a time the brine was dipped into a cistern where it was allowed to cool and settle. In this manner such material as had been mixed with the water in a mechanical way was deposited, and also oxide of iron, which was at first dissolved in the brine, but was made insoluble by boiling.

When the settling had been completed the brine was again conveyed by wooden tubes to certain ones of the row of kettles, known as "grainers." Into these was thrown a small quantity of clay which served as a nucleus for any remaining impurities, the whole being skimmed from the surface of the kettles. Beef's blood soon took the place of the clay, and this crude method is still followed in one small plant.

When salt had been precipitated in the kettles by boiling, it was thrown into "drainers," and the mother liquor, containing principally calcium chloride, drained off. The salt was then dumped into a shed known as the "salt house," and the drying completed. It was then barreled and marketed.

III. EXPANSION OF THE INDUSTRY

The industry grew rapidly and soon extended far beyond the areas already mentioned. The furnaces have long been abandoned, even the location of many having been forgotten. Under such conditions little more can be now done than to mention the principal localities.

Columbiana County.—If this was not the northernmost county producing salt, it certainly was the most northern important producer. The village Salineville, situated in the southeastern corner, was an early center of importance, and the same is true of the valley of Little Beaver on the east side of the county. A number of wells formerly existed in the valley of the Ohio between East Liverpool and Wellsville. A small quantity of salt was still made in this locality in 1876. In 1888 only one salt furnace was in operation in the county. This was located a few miles east of Lisbon, and was owned and operated by the New Lisbon Salt Company. The plant was built in 1868, and had a daily capacity of 65 barrels. The brine had a density of 10° B., and was supplied by two wells, one having a depth of 630 feet and the other 687 feet, the well heads being at the horizon of the Freeport coals. The bittern waters were used either as a fertilizer, or were allowed to waste.[1] The salt was sold principally in the vicinity. The plant was abandoned about fifteen years ago.

Tuscarawas County.—The salt industry in this county began in 1865, the first furnace having been located at Canal Dover. The wells started at the horizon of the Kittanning coals, and were about 900 feet deep. The brine had a density of 10° B., seven barrels having been necessary to produce one of salt.

Some bromine was found in the brine. After the salt had been precipitated, the remaining liquid was evaporated to a density of 45°B, and then distilled. One hundred and eighty gallons of this bittern yielded from fourteen to fifteen pounds of bromine.[2] Iodine was also present, but was not separated, owing to the expense.

In 1888 there were three furnaces in this vicinity having a combined daily capacity of from 180 to 200 barrels of salt.[3] The latter was handled by the Tuscarawas Valley Salt Company, the market being principally in the adjacent territory. As the price of salt fell lower and lower the operators found the profits growing smaller and smaller, until the industry could no longer be conducted with profit. Finally, about 1890 the furnaces were closed.

Morgan County.—The valley of the Muskingum which crosses the county from north to south is one of the oldest producers in the state. It appears that several furnaces were in operation as early at least as 1825. The brines, however, were weak, having a density of only 7½° B. Moreover, when the supply of wood became inadequate and coal was necessary, the furnaces were at a further disadvantage because the coal had to be transported some distance, thus adding to the expense. Since the Civil War the industry has declined until at present (1905) one furnace alone remains.

[1] *Geol. Sur. of Ohio*, vol. VI, p. 654.
[2] *Geol. Sur. of Ohio*, vol. III, p. 84.
[3] Vol. VI. p. 656.

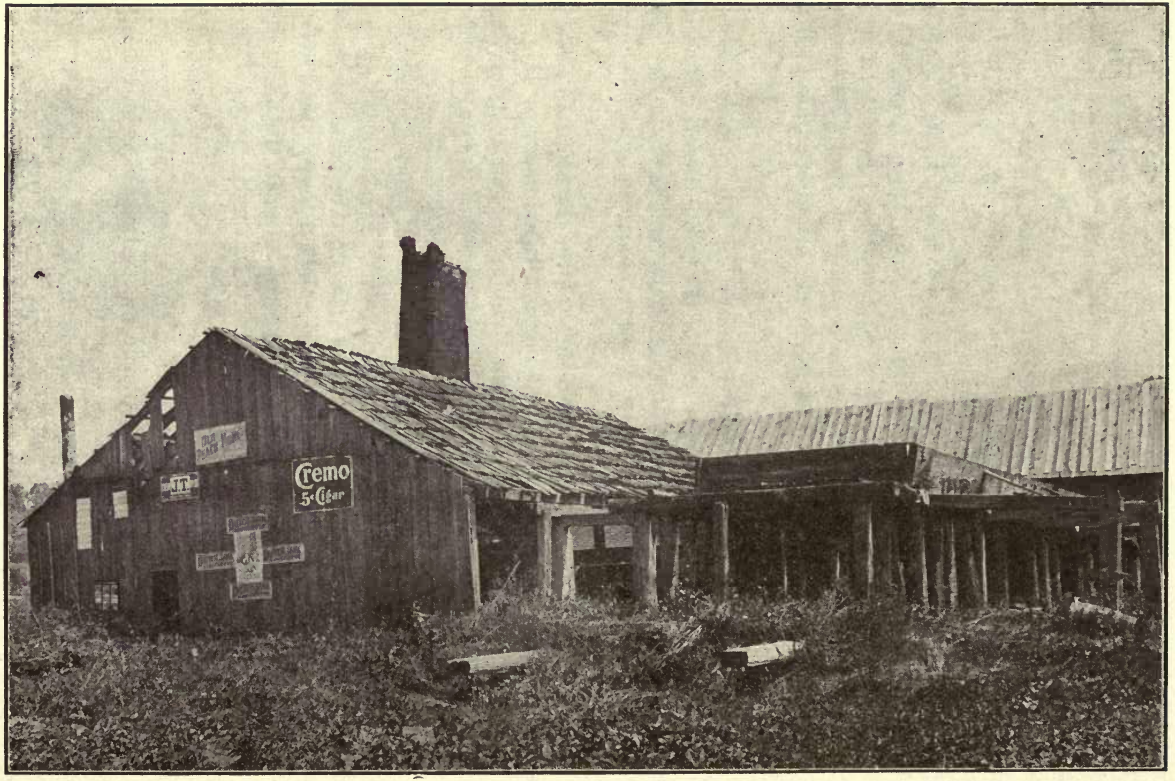

Figure 2.—Exterior view of an old salt works at Durant, Ohio.

This is located at Durant on the Muskingum river in the extreme northern part of the county. As late as the summer of 1903 the furnace was of the type of that a half century ago, and was known as the Big Bloom Salt Works. The brine was evaporated in iron kettles, 31 in number, each holding 90 gallons (see illustration). Beef's blood was the clarifying agent, and in other respects the process was similar to that of the pioneer days of the salt industry. The capacity of the plant was reported at 30 barrels of salt per day.

When this locality was revisited in August, 1904, the old plant had disappeared, but a new one stood near by. It was operated by the Muskingum River Salt and Coal Company, the capacity being 20 barrels per day. The plant had two vats, each 60x20x6 feet, and two grainers each 16x10x2½. The brine is evaporated with live steam, the fuel being coal. Beef's blood is still used as the clarifying agent, this being the only plant in Ohio retaining this primitive method. The brine which is obtained in the Salt sand is supplied by two wells having depths approximating 670 feet. The well heads are about 50 feet above the Middle Kittanning coal.

Zanesville is the principal market for the salt, shipment being by river.

Hocking Valley.—In early days a number of furnaces were in operation in this and tributary valleys, especially that of Sunday creek. Strong brines were found from 450 to 500 feet below the Middle Kittanning coal. As late as 1877 salt was made at McCuneville on the Shawnee branch of the Baltimore and Ohio railroad, and at Salina on the Hocking canal.[1]

Guernsey County.—In early days a number of salt furnaces existed in this county, but the quantity of salt produced was always small, and was consumed almost wholly in the adjacent territory. As late as 1887 one furnace was in operation. This was located about eight miles north of Cambridge, and was constructed in 1859. The capacity of the plant was less than ten barrels per day. The brine, having a density of 5° B., was supplied by a well 450 feet in depth. The works were abandoned about 1890.

IV. MEIGS COUNTY

Early History.—Meigs county is by far the most important salt producer in southeastern Ohio. In fact, it is probable that it has produced more than all others in that section of the state combined. Moreover, its furnaces are still active, though the yield is much smaller than in former years.

Salt making in Meigs county began on Leading creek, a short distance below Middleport. The date of the beginning is not known, but

[1]Vol. III, p. 115.

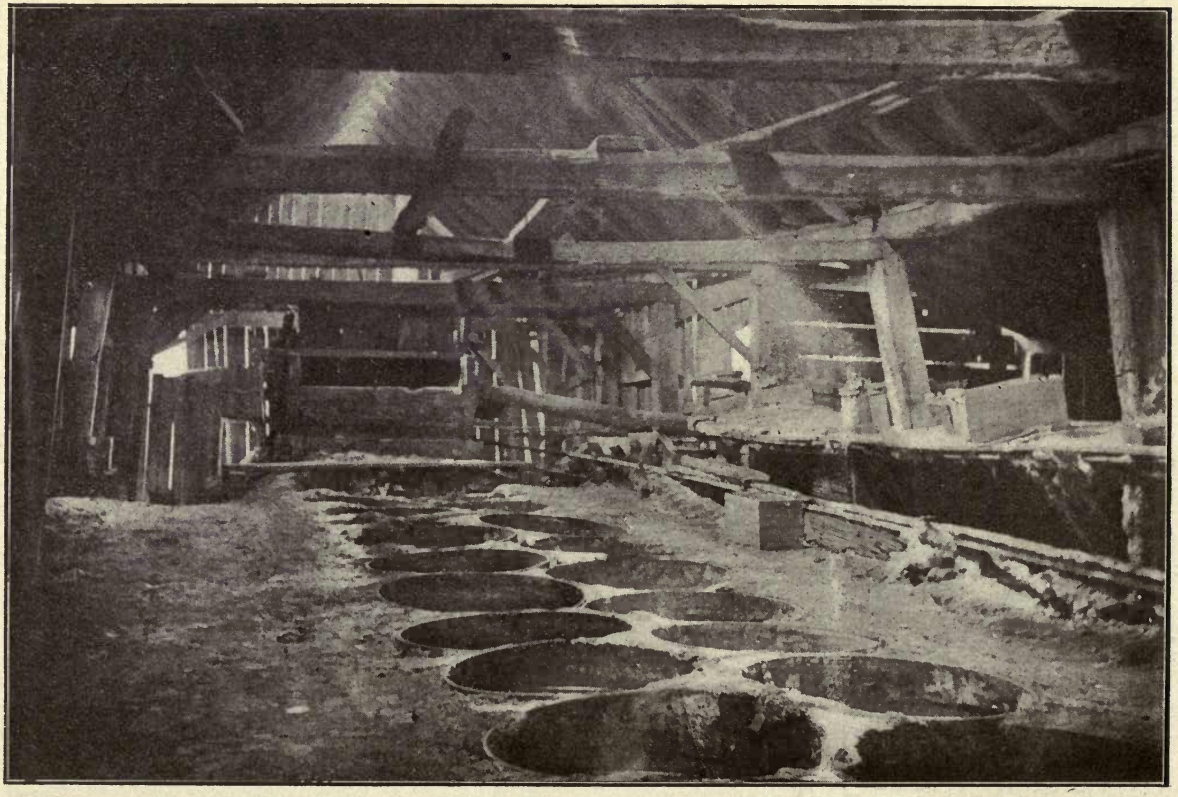

Figure 3.—Interior view of the old kettle furnace at Durant, Ohio.

was prior to 1847. The brine was evaporated in kettles, and the production small. These furnaces were abandoned many years ago.

About the year 1850 the industry began at Pomeroy. Pans were used from the start to evaporate the brine, the present process being substantially that introduced more than half a century ago. The possession of relatively strong brines, fuel in the adjacent hills, and river transportation made the industry profitable; the result being a rapid expansion of the industry, and Pomeroy became one of the best known salt centers in the country.

THE SALT PRODUCTION OF OHIO FROM 1882 COMPARED WITH THAT OF THE UNITED STATES.

[Barrels of 280 pounds.]

Year.	Ohio.	United States.	Ohio's percentage of total production,	Rank of state.
1882	400,000	6,412,273	6.2	3
1883	350,000	6,192,231	5.6	3
1884	320,000	6,514,937	4.8	3
1885	306,847	7,038,653	4.3	3
1886	400,000	7,707,081	5.1	3
1887	365,000	8,003,962	4.5	3
1888	380,000	8,005,881	4.7	4
1889	250,000	8,005,565	3.1	6
1890	231,303	8,876,991	2.6	6
1891	.....	9,987,945	....	..
1892	.....	11,698,890	....	..
1893	543,963	11,897,208	4.5	4
1894	528,996	12,968,417	4.0	4
1985	781,000	13,669,649	5.7	4
1896	1,662,358	13,850,726	12.0	3
1897	1,575,414	15,973,202	9.7	3
1898	1,682,247	17,612,634	9.5	4
1899	1,460,516	19,708,614	7.4	4
1900	1,425,283	20,869,342	6.8	4
1901	1,153,535	20,566,661	5.6	4
1902	2,109,987	23,849,221	8.9	4
1903	2,798,899	18,968,089	14.7	3
1904	2,455,828	22,030,002	12	3

The maximum number of furnaces on the Ohio side of the river is reported to have been 13 during or shortly after the Civil War. From that time the number steadily decreased; in 1887 it was seven; in 1905, five. The cause of the decline has been the immense expansion of the industry in New York and Michigan, and later in northeastern Ohio. These centers are relatively at a disadvantage so far as fuel is concerned, but this is more than offset by the saturated brine. So cheap is salt now made that only those plants most favorably situated survive. Every furnace in southeastern Ohio, except five at Pomeroy and vicinity, and one at Durant, has closed, and the near future may find the number still smaller.

The one cause for this decline has been the drop in the price of salt. About the close of the Civil War this salt sold for $2.50 per barrel.[1] In July, 1897, it sold for 47 cents, and has been marketed in small lots for 40 cents. This price included a barrel, the manufacture of which cost about 25 cents. In other words, 280 pounds of salt have sold for 15 cents. In July, 1903, the price was 65 cents, and in September, 1905, 70 cents.

A new factor appeared in 1899; this was the United Salt Company, or as it was popularly known, the "Salt Trust." It closed one or two plants and arranged to take the production of the others (with one exception) at an agreed price. The result was a marked advance, salt commanding $1.10 per barrel in the closing months of 1900. In the opening of 1901 the trust went into the hands of a receiver and the artificial price fell. By May, 1902, salt had dropped to 58 cents per barrel.

Much of the salt made in this locality during the last 25 years has been sold to J. B. Speed and Company, who shipped it in barges to Louisville, repacked and marketed it. After the collapse of the United Salt Company, the Pomeroy Salt Association was formed. This is merely a selling agency. The principal market for the Pomeroy salt is in the Lower Ohio and Mississippi valleys.

By-Products.—Were it not for the by-products, not a pound of salt would now be produced in this territory. It is claimed, and seems true, that the salt alone is made at a financial loss, but the bromine and calcium chloride have yielded sufficient returns to keep a small number of furnaces active.

Bromine was first made in this locality in 1868 at the Dabney salt works, long since abandoned.[2] The industry flourished from the start and soon made Pomeroy the best known bromine center in the United States. It is claimed that at one time the material commanded $10 per pound. By 1887 it had dropped to 33 cents, was selling at 22 cents in July, 1903, and about 15 cents in September, 1905. The principal cause of the decline has been the large yield of the Michigan salt fields. With the decline in the salt industry at Pomeroy there has been, of course, a proportional decrease in the output of bromine.

The writer has been unable to learn the date of the beginning of the calcium chloride industry in this territory. Mr. W. J. Root reports a large production in 1888, and hence the start antedates that period.[3] The earliest year that the writer has heard mentioned is 1884, but the beginning seems to have antedated that period.

Existing Furnaces.—Koehler's Excelsior Salt Works are located in the east end of Pomeroy where they were established in 1860. Since that time the furnace has been in operation, with the exception of short

[1] 280 pounds.
[2] *Geol. Sur. of Ohio*, vol. VI, p. 668.
[3] Vol. VI, p. 669.

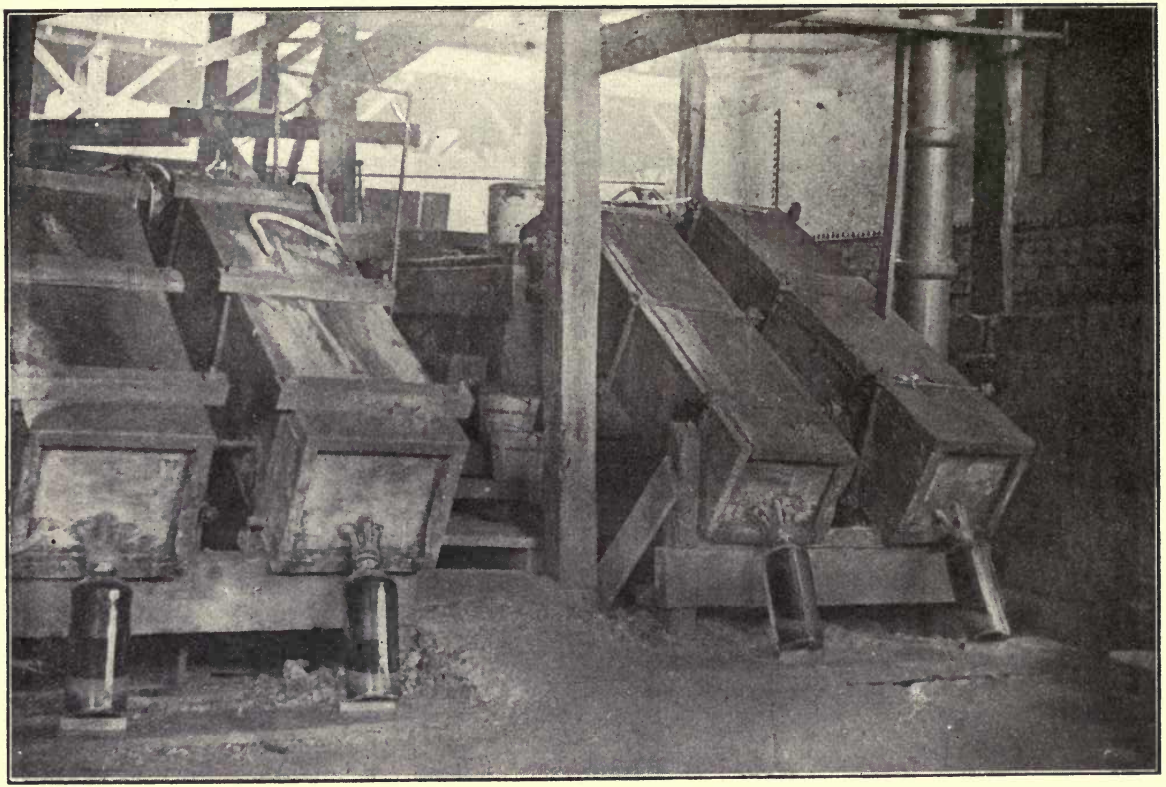

Figure 4.—Bromine plant at Pomeroy.

periods when closed for repairs. In 1884 the works came into the possession of B. Koehler, and are still owned and operated by members of his family. The plant has a daily capacity of 280 barrels of salt. Two bromine stills are operated, but the bittern waters containing the calcium chloride are sold to the Eureka Calcium Works, located on an adjacent lot. Four wells having depths ranging from 1,100 to 1,200 feet supply the brine. The wells were cased part way, when they were drilled, and this still remains in part in them. Three inch tubing is used in pumping. The company counts on one pound of bromine to two barrels of salt. On the average 40 people are employed.

The Buckeye Salt Company was established in 1865 and has been in operation ever since with occasional periods of enforced idleness for repairs. Mr. Charles McQuigg, the manager of the company, places the capacity of the plant at 350 barrels per day. Five wells are required to supply the necessary brine. The wells have depths ranging from 1,089 to 1,590 feet, the latter reaching the Berea grit. Like the Excelsior, the Buckeye Company disposes of its bittern waters to the Eureka Calcium Works. Fifty-five pounds of bromine are reported from 100 barrels of salt. The company mines its own coal, thus securing fuel at the minimum expense. In all 80 people are employed.

The Coal Ridge furnaces, located in the extreme east end of Pomeroy, were chartered in 1852, and began making salt two years later. The production ranges usually from 200 to 250 barrels per day. For fuel, run of mine coal is used, the company doing its own mining. Bromine and calcium plants are maintained, so that the company makes the most of the by-products.

The Pomeroy Salt Works are located near the western limits of Pomeroy, and were constructed about 1852. The company still exhibits a diploma for the best barrel of salt displayed at the state fair in 1855. Brine is supplied by three wells, ranging from 1,000 to 1,100 feet in depth. Bromine and calcium plants are maintained. The production of salt is about 225 barrels per day.

The Syracuse Salt, Bromine and Calcium Works began making salt in 1868. In 1904 the plant was practically rebuilt. The four wells are about 1,300 feet deep, the well heads starting 95 feet above the Pomeroy or No. 8 coal. About 200 barrels of salt per day are made. The company operates its own bromine and calcium plants. Run of mine coal is used for fuel.

Manufacture of Salt.—The process is quite similar in the plants now in operation. For convenience the methods of the Excelsior works will be described somewhat in detail, and then such modifications as are in use in the few remaining plants will be noted.

The brine is pumped from the wells into wooden tanks, of which there are two. These measure approximately, the one 70x12x6½ feet,

and the other 38x12x6½ feet. When first run into the tanks the water is clear, but soon changes to a light red, owing to the oxidation of the iron contained in the brine. These tanks are intended simply to collect the brine, any physical or chemical changes taking place being merely incidental.

From these tanks the brine is run into the heaters—long, shallow wooden boxes that are traversed by a copper pipe through which steam passes. This is the beginning of the evaporation, though in this stage the heat is sufficient simply to make the brine lukewarm.

The brine is run from the heaters into the furnace, entering the latter directly over the fire. The furnace is divided into four sections and each consists either of sheet or cast iron pans of variable length. The first section, consisting of ten cast iron pans, each ten feet long and three feet wide, lies directly over the fire. The pans are bolted together so that they really make one with numerous partitions. The second section duplicates the first. The third section consists of ten cast iron pans, each 8 feet long and 3 feet wide, all bolted together. The fourth section consists of one sheet iron pan, 35 feet long and 8 feet wide.

All pans are covered with a steam chest, consisting simply of a wooden box. Steam collected in this is used in evaporating the brine after it leaves the furnace.

From the furnace the brine is run into mud settlers, two in number. These are wooden boxes having dimensions of 160x8x4 feet. Each box or settler has a partition extending through it lengthwise, and each division of this has a copper steam pipe running through it, connecting at one end with the steam chest lying over the furnace, referred to in the preceding paragraph. Iron, clay and other impurities contained in the brine collect in these boxes, precipitation being aided by the addition of a small quantity of alum. That the impurities contained are few is shown by the fact that the boxes have to be cleaned only once a year.

From the mud settlers the brine is run into the draw settlers. The latter have the same length as the former, but are 10 feet wide and are not divided by a partition. Each is traversed by a steam pipe. These settlers serve to precipitate any impurities that escaped the mud settler; they also assist in evaporating the brine, some of the salt precipitating in them. Salt formed in this place has a light red color, due to the presence of a small quantity of iron, and is known in the market as red salt. It is used for glazing clay-wares. The salt is taken from these settlers once a year.

Each settler contains sufficient brine to supply the plant twenty-four hours. While the brine is collecting in one it is running from the other into the grainers.

The latter, seven in number, resemble the draw settlers, but are shallower, measuring only about two feet in depth. Each grainer is traversed lengthwise by three copper steam pipes. The evaporation is completed

in the grainers, the salt accumulating on the bottom; the bittern waters, containing the bromine and calcium chloride, remaining suspended over the salt.

This company makes three grades of salt, of No. 1 quality—fine, medium and coarse. The formation of crystals requires time; hence the lower the heat and slower the evaporation, the larger the salt grains. Production of small crystals or grains is aided by the addition of a small quantity of tallow or butter to the brine in the grainers. This forms a film on the brine, preventing the formation of thin sheets of salt on the surface and thus checking the evaporation. The result is a finer grained salt than when the grease is not used.

The salt is lifted by hand shovels from the grainers once each day and piled on boards which extend lengthwise over the middle of the grainers. After drying in this position over night, the salt is hauled in wheelbarrows to the salt house where drying is continued for approximately a week. The salt is then barreled and marketed.

The salt in the first six grainers is of No. 1 quality; that in the seventh is inferior, owing to the presence of some of the constituents of the bittern waters, and is sold for glazing and fertilizing purposes.

The Buckeye Salt Company.—This company has shown a commendable spirit by endeavoring to improve the process of salt manufacture. These efforts have required the expenditure of both time and money and have not always been successful. However, the results are on the whole favorable. Mr. Edward McQuigg is the manager of this company, and to him belongs the credit for the improvements.

When this plant was visited in July, 1903, furnace steam was used in the settlers only. Boilers supplied live steam for the grainers, the pressure in the former ranging from 40 to 60 pounds, and in the grainers about 20 pounds. Fresh water only was used in the boilers. The grainers were filled at intervals of twelve hours, but the salt was lifted or shoveled from them once only in twenty-four hours. As would be expected, the grainers with their higher heat produced a much larger body of salt per day than those heated by steam from the furnace, though the expense of the boilers and additional fuel offset the increased production of salt. This company was using alum in the settlers to clarify the brine, but expected to discontinue this, substituting lime. The change results from a belief that alum liberates some of the bromine.

The use of live or boiler steam to evaporate the brine was discontinued in October, 1904, the process having proven too expensive. The steam from the furnace pans is now collected in a wooden box known as the "equalizer." From this the steam is conducted to the six grainers, thus supplying equal heat to all, and in consequence producing an even grained salt.

The grainers are lined with tiling. A trial was made of cement, three inches on the bottom and four inches on the sides, but the experiment was unsuccessful, the cement cracking.

In the summer of 1904 the grainers were equipped with self-rakes. These consist of endless chains of brass, one on each side of each grainer. Cross pieces of wood covered with brass are attached to the chains. The latter are slowly turned by steam power, dragging the cross pieces along the bottom of the grainers and removing the salt as fast as formed.

The rakes drop the salt on a slowly moving belt, fourteen inches wide, which conveys it into the salt house. The self-rakes enable the company to dispense with ten salt lifters.

The salt is shipped largely in bulk in barges; also in barrels of 280 and 350 pounds, and sacks of 100 to 150 pounds.

Run of mine coal is used for fuel. It is claimed that one bushel produces one and one quarter bushels of salt, the latter bushel weighing fifty pounds.

The Coal Ridge Works.—Here they clarify the brine with lime and alum, sometimes the latter only. About one pound of alum is used to thirteen barrels of salt and one barrel of lime to 2,500 barrels of salt. The latter is left to dry about twenty hours on boards over the grainers, is then loaded in a small car and hauled by steam power to the salt house. In other respects the process is similar to that of the Excelsior Company.

The Pomeroy Salt Works.—This company uses the same process as the Excelsior and and Coal Ridge furnaces. Salt of coarse, medium and fine grain is made.

The Syracuse Salt, Bromine and Calcium Works.—This company employs the same general process that has been used in the Pomeroy field for half a century. A small quantity of lime is used in the furnaces and alum in the draw settlers. Salt is removed by hand. Run of mine coal is used for fuel.

The Pomeroy Salt Association Company.—This company in 1905 begun constructing a plant which is in many ways a marked departure from existing works.

First the brine will be lifted from the wells by compressed air and then run through crushed rock filters. From these the brine will be conveyed into an "evaporator" consisting of an iron cylinder containing steam coils. Here it will be boiled and then run into settlers and finally into the grainers. The steam will be conducted from the "evaporator" to the settlers and perhaps also to the grainers. The steam pressure in the "evaporator" will be low, not much more than is found in existing furnaces.

Two, perhaps three, settlers will be used, each measuring 176x12x2 feet. The grainers will measure 140x12x2½ feet, four or five being used. These will be equipped with self-rakes.

The grainers and settlers are all lined with two inch layers of sandstone obtained from the Rarden quarries near Portsmouth. Cotton is used for packing the joints in the settlers and grainers.

Calcium and bromine plants will be operated. It is expected that the plant will make 200 barrels of salt per day, beginning in January, 1906.

The Manufacture of Bromine.—After the salt has been removed from the grainers, the remaining liquid known as bittern and having a density of from 35° to 40° B., is run into a tank where it settles. It is then conducted to a still, the body of which is made of sandstone.

The bittern and chemicals are poured into the still through a funnel-shaped opening in the top, and withdrawn from the still by a small opening in the bottom, after the bromine has been removed. Steam is blown into the still by a small opening in the bottom, producing a temperature reported at about 180° F.

The condenser is simply a rectangular box about five feet long, through which pass three lead pipes extending from the still at one end to the bottle which collects the bromine at the other. Cold water is kept running through the box, condensing the bromine.

The bromine exists in the bittern as magnesium bromide ($MgBr_2$), comprising about one-half of one per cent. of the mass.[1] After bittern has been run into the still and steam turned in, sulphuric acid (H_2SO_4) is added, the proportion being one pound of the latter to twenty gallons of the former. This is followed by the addition of potassium chlorate ($KClO_3$), the ratio being one pound to sixty gallons of bittern.

The following reaction takes place in the still:

$$3MgBr_2 + KClO_3 + 3H_2SO_4 = 6Br + KCl + 3MgSO_4 + 3H_2O.$$

The bromine escapes as a gas, but is changed to a liquid in the condenser.

Formerly manganese dioxide (MnO_2) was used in place of the potassium ch'orate, the change resulting from the lower cost of the latter.

The Manufacture of Calcium Chloride.—After the bromine has been removed the liquid is conveyed from the still to a large cistern where it is treated with lime. This neutralizes any acid that may remain and helps to clarify the liquid. It is then condensed by boiling in an open pan. The process is completed in kettles containing steam coils, the calcium chloride remaining as a thick liquid which solidifies on cooling. In this condition it is shipped to many parts of the world.

Fuel.—The fuel used in all of these plants is coal. The Pittsburg, or, as it is locally known, Pomeroy coal, lies near the foot of the hills im-

[1] *Geol. Sur. of Ohio*, vol. VI, p. 663.

mediately back of the town, and serves admirably for the production of the necessary heat. In fact, were it not for this natural advantage the salt and dependent industries in Pomeroy and vicinity would have disappeared a decade ago. In some cases the companies have mined their coal, in others it has been purchased from a neighboring mine. Originally the poorest part of the seam and the slack appear to have been used in the furnaces and this is true to some extent at the present time. More generally, however, run of mine coal is now used.

All report that one bushel of coal will evaporate enough brine to yield a bushel of salt. Some claim that one bushel of this fuel will produce one and one quarter bushels of salt. This ratio depends largely on whether run of mine or the poorer parts of the coal are used.

Geological Considerations.—The surface rocks in the valley at Pomeroy lie at the summit of the Conemaugh formation, formerly known as the Lower Barren Coal Measures.[1]

The depth of the wells has undergone great variation. At first they were shallow, reported at about 300 feet. This reached the horizon of the first Cow Run sand, an important source of petroleum in Washington and Morgan counties. Later the wells were extended until a larger supply of brine was secured. When these proved inadequate, the wells were again deepened.

The following skeleton record of a well belonging to the Buckeye Salt Company is interesting in this connection. The well head is 25 feet below the Pomeroy or No. 8 coal.

Conductor	58 feet.
Shale	58– 550 feet.
White and gray sand	550– 870 feet.
White sand and slate	870– 960 feet.
Big Salt sand	960–1130 feet.
Sand and white shale	1130–1495 feet.
Berea grit	1545–1570 feet.
Total depth	1590 feet.

Brines were reported as follows:

Depth in feet.	Density.
320	6° B.
710	9° B.
980	9° B.
1550	16° B.

It is seen that the brine found in the Berea is much denser than that found in overlying rocks. The quantity, however, was small, and the well is pumped from the horizon of the "Big Salt sand." This company has five wells, the depths varying from 1,089 to 1,590 feet, the latter penetrating the Berea. The Excelsior Company has four wells whose depths range from 1,100 to 1,200. Wells drilled farther east are deeper, since the rocks dip in that direction.

[1]*Geol. Sur. of Ohio*, Fourth Series, Bull. No. 7, p. 4.

When drilling first began in this territory, the water is said to have risen nearly to the well heads, and in some cases actually overflowed. As pumping progressed the reservoirs of brine were lowered, and at the same time the tubing was extended deeper into the wells. In this manner the tubing followed the brine in its descent.

For many years the Excelsior works have pumped from the 750 foot level. The brine is said to rise slightly when the wells in the neighboring plant are not in action.

The density of the brine increases in the direction of the dip of the rocks; that is, to the southeast.

This is shown by the following data:

	Density of brine.	Temperature of brine.
Pomeroy Salt Works, west end of Pomeroy	8° B.	61½° F.
Koehler's Excelsior Salt Works, east end of Pomeroy	8½° B.	63° F.
Syracuse Salt, Bromine and Calcium Works	10½° B.	62½° F.

The variation in density is due to the heavier brines seeking the lower level. The variations in temperature result in part from the different conditions under which the measurements were made, it not being possible in all cases to ascertain the temperature directly at the well head. The variation is due also in part to the greater depth of the wells to the southeast.

The quantity of brine that has been taken from these rocks is enormous, much more than the rocks could at any one time contain. This great excess has doubtless been derived from surrounding territory. The brine bearing strata dip towards Pomeroy from the northwest. As the brine has been pumped from the wells, the supply has been renewed from the rocks lying at a higher level.

Doubtless the brine was once a part of the ocean. As the sand or gravel, now composing the salt bearing rocks, was deposited on the ocean floor, sea water filled the spaces between the grains and pebbles and has since remained in that position.

The composition of sea water, according to Dittmar, is as follows:

$NaCl$	77.758
$MgCl$	10.878
$MgSO_4$	4.737
$CaSO_4$	3.600
K_2SO_4	2.465
$MgBr_2$	0.217
$CaCO_3$	0.345

Comparing this analysis with that of the brine given on the following page shows points both of resemblance and difference. It must be borne in mind, however, that the Pomeroy brines were from near the shore, perhaps from a land locked sea, and hence might vary considerably from those of the open ocean. This fact explains the presence of the relatively large amounts of bromides and iodides, since these substances are contained in certain marine plants. Probably conditions were very favorable for these plants in the early sea in the vicinity of Pomeroy.

Chemical Examination.--This was made by Professor C. W. Foulk of the State University, and unless otherwise stated all work of this nature is to be credited to him.[1] An analysis of salt obtained in 1905 from Coal Ridge Salt Works, Pomeroy, gave the following results:

Moisture	7.42
Sodium chloride	91.31
Sodium sulphate	0.00
Calcium chloride	0.95
Magnesium chloride	0.32
Silica, iron and aluminum oxide	0.00

A sample of brine from the wells of the same company was also examined. This brine evidently contains most if not all of its iron in the ferrous condition since the characteristic precipitate forms on standing. Following are the results of the analysis:

	Grams per liter of brine.	Grains per U. S. gallon of brine.
Silica	0.012	0.70
Iron and aluminum oxides	0.083	4.81
Calcium chloride	14.340	831.72
Magnesium chloride	5.590	324.22
Magnesium bromide	0.155	8.99
Strontium chloride	0.257	14.91
Barium chloride	0.343	19.89
Sodium chloride	84.300	4889.40
Sodium iodide	0.004	0.23
Sodium sulphate	0.000	0.00
Potassium chloride	0.114	6.61
Lithium	Trace	Trace
Specific gravity	1.075	

If the rather large numbers above for the content of sodium chloride be recalculated in more familiar units the strength of the brine is found to be 0.70 pound salt per gallon.

An analysis of the Pomeroy brine was made in 1888 by Root,[2] who apparently calculated the results as percentages of the sum of the constituents found. A comparison of the two analyses made at such widely different times is of interest, and accordingly in the following table Root's results of 1888 are given together with the present analysis which has been recalculated as percentages of the total.

	Analysis of 1906.	Analysis of 1888.
Specific gravity	1.075	1.071
Sodium chloride	80.134	79.273
Calcium chloride	13.633	14.397
Magnesium chloride	5.314	6.097
Magnesium bromide	0.147	0.097
Sodium iodide	0.004	0.012
Silica	0.079	0.043
Iron and aluminum oxides	0.011	0.082
Potassium chloride	0.108	.....
Strontium chloride	0.244	.....
Barium chloride	0.326	.....

[1] *Geol. Sur. of Ohio*, vol. VI, p. 663.
[2] For a brief description of the methods employed, see appendix.

The absence of sulphates from the southern Ohio brines has been noted as remarkable, distinguishing them from others. This is now easily explained in light of the barium salt which they carry. Any sulphates would long since have been precipitated.

V. NORTHEASTERN OHIO.

The salt industry in northeastern Ohio is of recent origin, but the development has been such that the quantity of salt produced greatly exceeds that in the southeastern part of the state. In fact were it not for the territory now under consideration Ohio would not rank as an important salt producer.

The industry began at Newberg about 1889, and has extended to Cleveland, Kenmore (near Akron), Wadsworth and Rittman. The growth has been rapid and seems capable of almost indefinite expansion.

The Wadsworth Salt Company.—This plant is the result of drilling for oil. About the year 1886 an experienced oil driller from Pennsylvania chanced to pass through Wadsworth on the Erie railroad. Just west of the village he noticed, as he rode by, a rock exposure which he thought indicated deposits of oil below. After reaching his home he took up the matter by correspondence with the postmaster at Wadsworth. Later he came to the village, and raised by popular subscription sufficient funds to drill a well. Before the test was begun 15,000 acres of land were leased.

The driller expected to find oil at a depth similar to that at Washington, Pennsylvania. Work was begun about 1889 and progressed slowly, so that more than a year elapsed before the depth of 3,200 feet was reached. The only fuel found was a small flow of gas, but at a depth between 2,400 and 2,500 feet rock-salt was penetrated. The well was abandoned.

The disclosure of the drill naturally started discussion among citizens of the community and others interested in the salt industry. This resulted in 1891 in the organization of a salt company. Two years later the organization was incorporated, the capital stock being $100,000.

The company secures its brine from two wells; the first was completed early in 1892, and is 2,707 feet deep, the second was finished in 1898, being 2,685 feet deep. No logs of these wells were secured, but the manager of the company, Mr. F. W. Boyer, reports that four beds of rock-salt having an aggregate thickness of 140 feet were found, and below these a honeycomb limestone 100 feet in thickness containing salt in the cavities. The manager states that salt is taken from the higher two beds only.

The rock-salt is dissolved by water which is supplied by wells, 18 in number, and about 100 feet in depth. A continuous stream of fresh

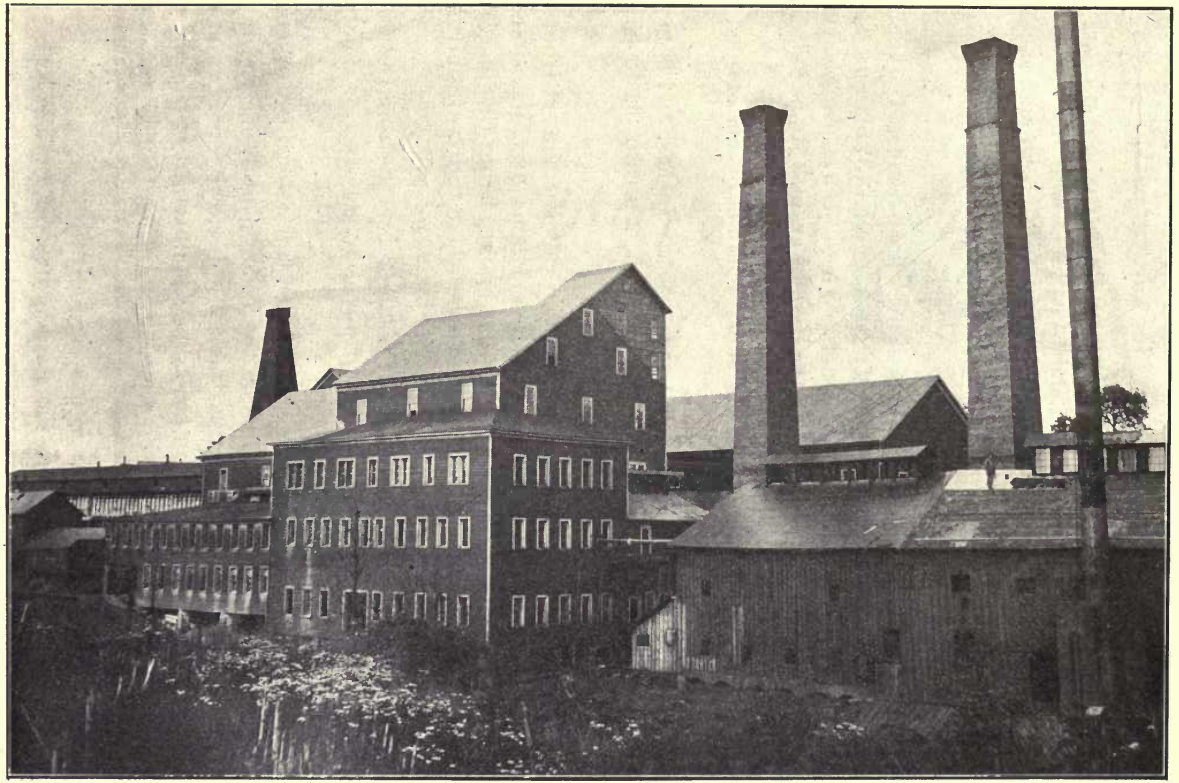

Figure 5.—Exterior view of a modern salt works at Wadsworth.

water is run into the wells. The salt beds uniting the two wells have been dissolved in places, and in consequence the two are connected by a subterranean channel.

From the wells the brine, saturated or nearly so, is forced into a large reservoir from which it is run into the vacuum pans.

The Vacuum Pans.—The company uses the vacuum process entirely. Two vacuum pans are used, each forty feet high and ten feet in diameter. Each pan contains 800 evaporating tubes, two and one-half inches in diameter and about four feet in length. In the center of this group of tubes is a large one, twenty-four inches in diameter and about six feet in length.

Heat in the pans is supplied by steam of three grades, (1) exhaust; (2) low pressure, from thirty-five to forty pounds; and (3) high pressure, from 125 to 140 pounds to the square inch. The object of using varying temperatures is to obtain salt having the desired grain. As has already been stated, the more rapid the evaporation the finer the salt. A temperature of approximately 135° F. is most commonly maintained in the pans.

The vacuum in the pans is usually twenty-five inches, and is maintained by an air pump and by the condensation of steam produced by the evaporation of the brine.

Drying, Screening and Marketing.—The salt is removed from the evaporators by buckets attached to endless chains and deposited in wooden bins where it dries from two to four hours. From this place the salt is removed in hand carts to the warehouse where it dries from thirty to ninety days, depending chiefly on the demand for salt.

Sometimes a small quantity of salt is taken directly from the warehouse and marketed. By far the greater quantity, however, is removed in hand carts to the drying department.

The driers consist of revolving metal kilns, thirty-four feet in length and six feet in diameter. The kilns lie nearly horizontal, one end being slightly elevated so that on rotating the salt will slowly creep from the higher end to the lower. Heat in the kilns is maintained by steam, and the drying is further promoted by hot air blown through the kilns. About twenty-five minutes are required for salt to pass through the drier.

After having been dried the salt is carried to the top floor where it is screened and then conveyed to the storage bins. From these the salt is packed and marketed. The refuse material resulting from screening is sold for making ice cream and other purposes not requiring a pure salt.

The plant has a capacity of 1,200 barrels of salt per day, and furnishes employment when working in full for 150 people, men, women and boys.

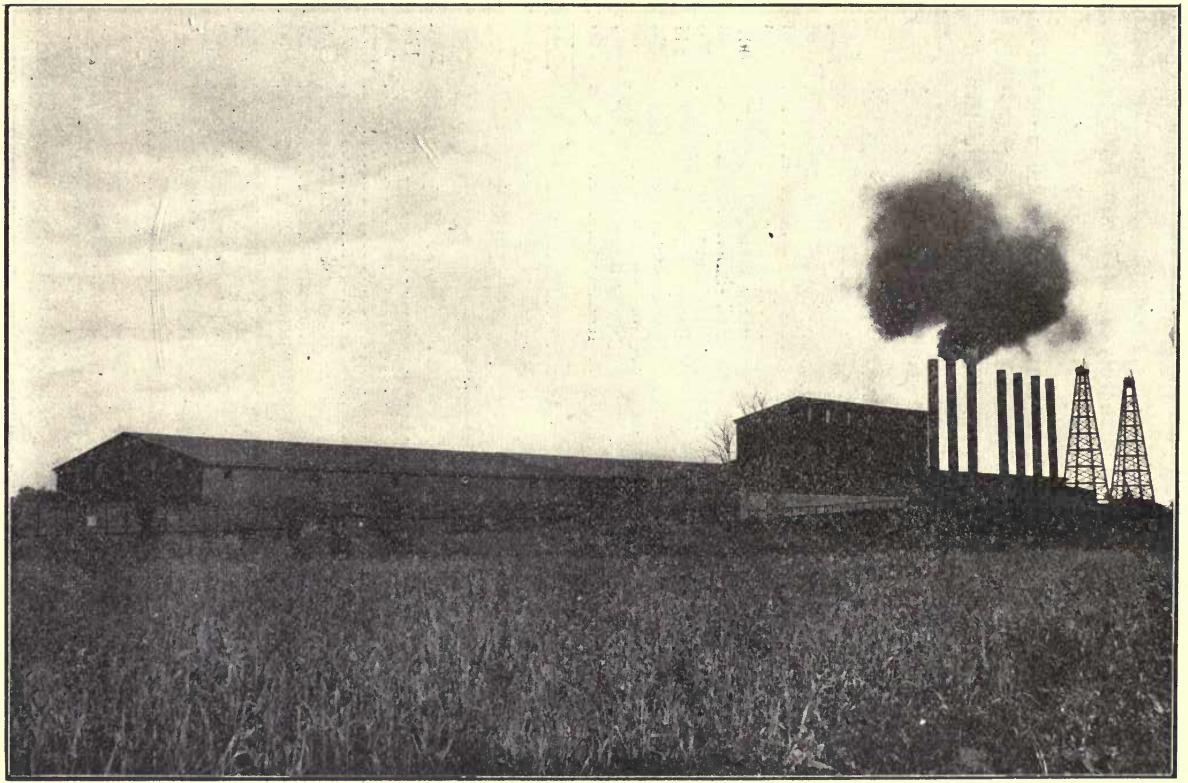

Figure 6.—Exterior view of a modern salt works at Rittman, Ohio.

Ohio Salt Company.—This plant is located at Rittman in the northeast corner of Wayne county. The company was incorporated in March, 1898, with a capital stock of $250,000. The first salt was made in the autumn of that year, and for the ensuing twelve months the average daily production was 600 barrels. From time to time the capacity of the plant has been increased. In July, 1903, it was 1,500 barrels, and in May, 1905, 2,000 barrels.

The company has four wells each approximating 2,625 feet in depth. Two of these are only 100 feet apart, but the other two are 600 feet from each other and from the first two. A skeleton record of two of these wells is given below:

WELL NO. 1.

		Feet.
Clay		40
Quicksand and gravel		133
Gray sandstone (Berea)		20
Bedford and Ohio shales	Black shale	1007
	Red shale	50
	Slate and shells	250
	Brown shale	535
Corniferous and Monroe formations	Limestone	268
	Gray sandstone	30
	Shelly limestones	225
Salina formation	Rock-salt	66
Total		2624

WELL NO. 3.

		Feet.
Drift		171
Cased out fresh water at		240
Struck mineral water at		2272
Cased this out at		2324
Salina formation	Rock-salt at 2513 feet	6
	Limestone	25
	Rock-salt	30
	Limestone	5
	Rock-salt	35
	White slate	30
	Limestone	7
Total depth		2651

Fresh water is pumped into the wells, and brine saturated or nearly so lifted from them. The wells only 100 feet apart have already had sufficient salt removed between them to form an underground connection between the two. One of the more distant wells has in a similar way been connected with the first two.

Salt Manufacture.—The company uses both the vacuum pans and grainers. Of the former there are two; one has 1,004 tubes each four

feet in length and two and one-half inches in diameter, and a central tube four feet in length and two and one-half feet in diameter. The other pan has 840 tubes each four feet nine inches in length and two and one-half inches in diameter, and a central tube four feet in length.

Only one pan is operated at a time, each being used twenty-four hours and then lying idle for an equal time. After having been used the pans are washed with cold fresh water to remove any salt that may have been deposited in them during the preceding day. Gypsum is slowly deposited in the tubes, and has to be removed from them by boring once in two months. Formerly this operation had to be made every twelve hours. It is claimed that the rate of deposition of gypsum depends very largely on the methods followed in evaporating the brine.

The temperature in the pans is reported to be approximately 120° F., and the vacuum from twenty-seven to twenty-eight inches. The temperature just referred to is maintained both by exhaust and live steam.

After leaving the pans the salt passes through substantially the same processes as those already described at Wadsworth. Part of the salt is marketed before drying. This is shipped in bags and barrels. Some, however, is shipped in bulk in box cars. The dried salt is packed in bags in sizes weighing from one to 224 pounds. The small bags weighing from one to five pounds are filled by machinery. The latter is operated by girls, an average day's work for one girl being 5,000 bags of three pounds each. For the smaller amounts a patent bag which does not require sewing after filling is used. The bags weighing from eight pounds and above, when filled, are sewed by hand.

This salt is used principally for table and dairy purposes. Any dirty salt finds a market for glazing, fertilizing, ice cream manufacture, etc.

The Grainers.—There are seven of these. Two measure each 160x10x2 feet. These are provided with self-rakes, consisting of two endless iron chains, one on each side of the grainer, to which are attached transverse flat strips of iron. The latter draw the salt out of the grainer as fast as it accumulates on the bottom. This is a distinct improvement over the old method of removing the salt with hand shovels.

Salt making in these grainers is a continuous process. Brine runs into them day and night, and salt is raked out as fast as formed. Each grainer makes 150 barrels of salt per day.

Five grainers measure each 160x12x2 feet. These are not provided with self-rakes, the salt being removed by shovels with hand labor.

Located about 300 feet from the plant under consideration are the works of the Ohio Box Board Company. This company obtains its electrical power from the salt works and furnishes the latter with exhaust steam. This is used in the vacuum pans and to a smaller extent in the grainers. Some live steam also is used.

Grainer salt commands a higher price than the vacuum, the difference amounting to about ten cents per barrel.

The company reports that it uses neither alum, lime, soda, nor anything else in the brine.

Fuel.—The company owns and operates its own mines. These are located some miles distant, but nevertheless furnish the necessary fuel at the lowest expense.

Market for Salt.—No traveling salesmen are employed. Among the heavy consumers may be mentioned H. J. Heinz and Company and The National Biscuit Company. Large quantities are shipped to various parts of the United States and Canada. Dirty salt is sold for fertilizing, glazing, melting ice on car tracks, etc.

The Union Salt Company.—This company succeeded the United Salt Company, which controlled the pioneer plants in northeastern Ohio. These were first, in point of time, the plant at Newberg. This was a direct result of drilling for gas for a Cleveland rolling mill. The sand pump brought glassy particles that proved to be rock-salt, and the construction of the furnace was soon begun.

On account of the unusual interest of this pioneer record, the drillers' log, as interpreted by Dr. Edward Orton, is given below:[1]

		Thickness of formation feet.	Total depth feet.
Drift		40	40
Ohio and Bedford shales		1310	1350
Corniferous and Monroe formations	Limestone	310	1660
	Sand containing lime	40	1700
	Limestone	290	1990
Salina formation	Rock-salt and shale	164	2154
	Shale	15	2169
	Limestone	81	2250
	Rock-salt	50	2300
	Shale, blue	40	2340
	Sand	20	2360
	Shale	18	2378
	Limestone	22	2400
	Rock-salt	20	2420
	Shale	10	2430
	Limestone	40	2470
	Rock-salt	5	2475
	Shale	8	2483
Niagara formation	Limestone	167	2650
	Oil sand	8	2658
	Limestone	22	2680
	Oil sand	6	2686
Clinton formation	Limestone	64	2750

Later, drilling was continued through "limestones of the same general character" to a depth approximating 3,000 feet, when the tools became fast and work of necessity ceased.

[1] *Geol. Sur. of Ohio*, vol. VI, p. 352.

Chemical analyses have been made from drillings taken at several horizons. These show that the shales associated with the rock-salt consist largely of calcium sulphate, and that the top of the Niagara is strongly magnesian and the lower part almost a pure dolomite.

The grainer process alone was used in making salt. The plant ceased work in the fall of 1902 and was dismantled in 1905. Its capacity was 700 barrels per day.

The only plant of this company in operation in 1905 was the one located on the lake front at the foot of Madison street. This began making salt about 1890. The brine is supplied by five wells having depths approximating 2,000 feet.

Following is the log of well No. 4, drilled in 1893:

Drift	Sand	15 ft.	267 ft.
	Quicksand	6	
	Blue clay	129	
	Sand and clay	9	
	Quicksand	76	
	Sand and gravel	6	
	Gravel and clay	26	
	316 ft. of 10-in. casing.		
Shales (Ohio)		723	723
	379 ft. of 8¼-in. casing.		
Corniferous, Monroe and Niagara formations	Limestone	390	775
	White sandstone	33	
	Limestone	11	
	White sandstone	16	
	Limestone	315	
	Limestone and rock-salt	10	
Salina formation	Rock-salt	16	229
	Limestone	16	
	Rock-salt	19	
	Limestone	4	
	Rock-salt	59	
	Limestone	21	
	Rock-salt	37	
	Limestone	4	
	Rock-salt	37	
	Slate	16	
	Total depth (steel line meas.)		2006½ft.

A "heavy" flow of gas was reported at 150 feet; water at 159 and 235 feet, and a "light" flow of gas at 242 and 306 feet.

Both live and exhaust steam is used in the vacuum pans. In some grainers live steam is used, in others exhaust steam. The fuel is partly run of mine and partly slack coal.

The company manufactures the barrels and bags used in marketing the salt.

When the plant is running in full it produces about 1,800 barrels of salt per day.

The third plant of the Union Salt Company is located at the foot of Marquette street. Thus far (1905) it has never been in successful operation.

An effort has been made here to introduce an entirely new method in salt manufacture in Ohio. The plan consisted essentially of heating the brine and then forcing it into a spray. Through the latter hot air was forced. This was expected to carry away the water, the salt collecting below. The plan was unsuccessful.

The company expects to remodel this plant and start it in operation in the near future. While the proposed plan is new to Ohio it is not new to the country, being reported to have been successfully tried in Michigan.

The brine will be heated to a temperature of about 230° F. and then run into grainers. It will move slowly in these from one end to the other depositing salt all the while. Since the brine in the higher end of the grainer is hottest, it will deposit the finest grained salt. The salt will gradually become coarser toward the lower end of the grainer.

The brine in the grainers from which the salt is not deposited will be conveyed to other grainers for making coarser salt or forced back to the heaters and then returned again to the grainers as before.

In this work two larger grainers, each about 80x40x2 feet, will be used. These, however, will be connected with others for making coarser salt.

All will be equipped with self-rakes for removing the salt.

The points claimed for this system, which has just been outlined, are:

1. It will be automatic and continuous.
2. It will largely reduce the labor.
3. It will abolish the present necessity of piping the grainers.
4. It will require less fuel.

The company's market extends from the Atlantic to the Mississippi river, and as far south as Alabama.

The Cleveland Salt Company.—This company was organized in 1897, and began making salt in 1900. The plant is located at the corner of Second and Central avenues.

Brine is supplied by three wells, each approximating 1,950 feet in depth. The following skeleton record of well No. 2 shows the position and thickness of the salt beds:

Shales and limestone	1821 ft.
Rock-salt	10
Limestone	5
Rock-salt	5
Limestone	5
Rock-salt	10
Limestone	22
Rock-salt	72
Limestone	2
Total depth	1952 ft.

The company uses the vacuum and grainer methods in making the salt. The two vacuum pans each measure fifteen feet in diameter, and

each has a capacity of 150 tons of salt per day. A temperature of 125° F. is reported in the pans, and a vacuum of twenty-five or twenty-six inches. As elsewhere gypsum causes trouble. It accumulates in the tubes of the pans and has to be bored out every other day.

Three of the four grainers are equipped with self-rakes. The fourth is used to make a coarse salt, and has a capacity of about five and one-half tons per day.

The brines in the pans and grainers are heated by exhaust steam obtained from the Cleveland Electric Railway Company and from the company's own boilers. It is claimed that this is much less expensive than using live steam entirely. The brines are not treated with chemicals of any kind.

That part of the grainer salt prepared for domestic use is screened and dried, the methods being similar to those already described.

The company employs from forty to sixty people. It does not manufacture the barrels used.

The company's market extends from the Atlantic to the Mississippi river, and as far south as Alabama.

The capacity of the plant is given at 90,000 tons of salt per year.

The Colonial Salt Company.—This company was incorporated under the laws of New Jersey in February, 1901, with paid-up capital of $350,000.

The works are located at Kenmore, between Akron and Barberton, in Summit county. The writer was not permitted to enter the works, and hence this report is not as complete as it would otherwise have been.

Brine is supplied by six wells, having a depth approximating 2,800 feet. Below is a log of one of these:

Drift	115 ft.
(Water at 110 feet).	
Slate and shells	1943
Limestone	694
(Water at 2398 and 2465 feet).	
Salt	7
Limestone	4
Salt	37
Limestone	22
Salt	30
Limestone	4
Total depth	2856 ft.

The rock-salt is dissolved by water from wells 150 feet in depth. In the evaporation of the brine both vacuum pans and grainers are used. No attempt is made to precipitate the gypsum which the brine contains.

The two vacuum pans are said to measure seventeen feet in diameter and to have 2,000 tubes. The heat used is by the double effect method. Live steam is used in the first pan, and the steam formed in

this pan is conducted to the second one. A vacuum of fifteen inches is used in the first and from twenty-five to twenty-eight inches in the second pan.

Fourteen grainers are used. Eight are supplied with self-rakes, and in the remaining ones the salt is removed with shovels by hand. Evaporation in the eight just referred to is produced by live steam, and the latter, having passed through these grainers, is conducted to the remaining six, supplying heat to them. It follows that the last grainers referred to produce coarser salt than those supplied with live steam.

The company claims to produce by all methods about 400 tons of salt per day. The salt finds a market in the Central States, New England, South, and to some extent in the far West.

Chemical Examination.—A sample of brine from the wells of the Union Salt Company, Cleveland, gave the following results:

	Grams per liter of brine.	Grains per U. S. gallon of brine.
Silica	0.000	0.00
Iron and aluminum oxides	0.000	0.00
Calcium chloride	1.033	60.28
Calcium sulphate	4.857	283.40
Magnesium chloride	0.462	26.80
Strontium chloride	0.089	5.16
Barium chloride	0.000	0.00
Sodium chloride	310.977	18161.00
Potassium chloride	0.713	41.35
Sodium iodide	0.000	0.00
Magnesium bromide	0.012	0.70
Lithium salts	Trace	Trace
Specific gravity	1.204	

Recalculated in more familiar units, the brine was found to contain 2.59 pounds of salt per gallon. That at Pomeroy, as already stated, has only 0.70 pound of salt per gallon.

The following analyses show the composition of the salt made in northeastern Ohio. The samples tested were all made by the vacuum pan process, except No. 5 which is a grainer salt.

1. "Chippewa Salt," Ohio Salt Co., Rittman.
2. "Standard Granocrystal," Wadsworth Salt Co., Wadsworth.
3. "Buckeye," Union Salt Co., Cleveland.
4. "Quality and Quantity," Union Salt Co., Cleveland.
5. "No. 1 Common Fine," Union Salt Co., Cleveland.

Number.	1	2	3	4	5
Moisture	0.52	0.57	0.37	0.39	1.22
Sodium chloride	98.09	97.61	98.81	98.33	97.91
Calcium sulphate	1.19	1.70	0.68	1.02	0.68
Calcium chloride	0.20	0.12	0.14	0.26	0.08
Magnesium chloride	0.00	0.00	0.00	0.00	0.07
Silica, iron and aluminum oxides	0.00	0.00	0.00	0.00	0.04

Limits of the Field.—The salt producing area in northeastern Ohio is large, but not unlimited in extent. Thus far the furnaces are restricted to four counties—Cuyahoga, Summit, Medina and Wayne. However, the salt deposits are not limited to this territory. That the beds in question extend farther east is shown by the following record of the Hadsell well near Cortland, in the eastern part of Trumbull county:

			Depth of formation feet.	Total depth feet.
Drift			40	40
Shale			60	100
Berea grit			160	260
Bedford and Ohio shales			2396	2656
Corniferous and Monroe limestones			583	3239
Salina formation	Rock-salt	12 ft.	471	3710
	Limestone	5		
	Rock-salt	2		
	Limestone	3		
	Rock-salt	10		
	Limestone	49		
	Rock-salt	29		
	Limestone	10		
	Rock-salt	52		
	White shale	18		
	Limestone	36		
	Rock-salt	10		
	Limestone	50		
	White shale	15		
	Rock-salt	30		
	Limestone	10		
	Rock-salt	3		
	White shale	90		
	Limestone	5		
	Blue shale	32		
Total depth				3710

It may be noted that this record shows 148 feet of rock-salt. If the alternating strata of limestone are similar to those farther west in having many large holes filled with salt, then the total quantity is much in excess of the 148 feet. The record shows that the salt strata extend to the eastern limits of the state.

To the south the limit of the salt deposits has not been determined. This follows from the fact that the strata dip to the south and east, and hence the salt horizon lies so deep that it has not been reached by the drill.

Westward the limit has not been determined. It cannot extend as far as Sandusky, however, as the following record shows:[1]

Drift	10 ft.
Corniferous limestone	100
Monroe and Niagara limestone	970
Niagara shale and Clinton formation	105
Medina shale	175
Cincinnati shale and limestone	500
Utica shale	310
Trenton limestone at	2210

[1]*Geol. Sur. of Ohio*, vol. VI, p. 195.

The Monroe and Niagara limestones were found to contain numerous layers of gypsum, fourteen having been noted, but none of salt.

However, considering the area beneath which salt has been demonstrated to exist and the number and thickness of the beds in question warrants the conclusion that northeastern Ohio contains enough salt to supply the entire country for an indefinite period.

Univ. of California

APPENDIX

METHODS OF ANALYSIS

Salts.—From two to three grams were subjected to the conventional methods for the determination of silica, oxides of iron and aluminum, calcium and magnesium salts. The sulphates were precipitated from five gram samples. For the estimation of moisture three grams were ignited to constant weight at a dull red heat, the loss in weight being called the moisture. Sodium chloride was determined by difference.

Brines.—Silica and iron and aluminum oxides were determined in 100 cubic centimeter samples. For calcium and magnesium salts fifty cubic centimeters were used, the results being corrected for strontium and barium. Sodium was determined in a ten cubic centimeter sample of the Pomeroy brine and in four cubic centimeters of the one from Cleveland. Accuracy of measurement of these small amounts was insured by diluting a larger portion and taking an aliquot part. Sulphates were precipitated from 250 cubic centimeters of the Cleveland brine. For strontium from fifty to 100 cubic centimeters were used, the strontium and calcium being twice precipitated as oxalate, and after transformation into nitrates subjected to the ether-alcohol separation. The residues of strontium showed neither calcium nor barium on examination with the spectroscope. Potassium was estimated in 100 cubic centimeter samples after precipitating the sodium chloride with hydrochloric acid gas. This was readily accomplished in a glass-stoppered washing bottle. A blank was tried to determine whether the acid attacked the glass and gave negative results. The filtrates from the potassium platinic chloride were examined with the spectroscope for lithium. Both brines showed traces, the Cleveland brine seeming to have more than the one from Pomeroy. Barium was determined by precipitating from 500 cubic centimeters with sulphuric acid. The resulting precipitate was fused with sodium carbonate, extracted with water and the barium precipitated as chromate from the acetic acid solution of the carbonates.

For bromides and iodides 500 cubic centimeters were treated with an excess of sodium carbonate, boiled and filtered. The filtrate was evaporated, the salt separating being filtered off from time to time and washed with alcohol. In this way the amount of salt was reduced to a few grams when the final residue was gently ignited and the resulting black mass boiled with water and filtered. This was diluted to about 200 cubic centimeters, placed in a flask together with two cubic centimeters of sulphuric acid and ten cubic centimeters of a ten per cent. solution of sodium

nitrite and distilled with steam, the iodine evolved being received in an ammoniacal solution of hydrazine sulphate from which it was precipitated with silver nitrate after acidifying with nitric acid. The residual liquid in the flask was made alkaline with caustic soda and concentrated to about 50 cubic centimeters, when it was made just acid with sulphuric acid and returned to the distilling flask where it was distilled with steam after adding 1.5 grams of potassium permanganate and ten cubic centimeters of strong acetic acid. The bromine evolved was collected and determined as for iodine.

Repeated trials with the brines and with artificial brines made from salt and Columbus city water and containing known amounts of iodides and bromides showed that the above methods failed completely in the presence of a large excess of sodium chloride. Chlorine invariably distilled over, sometimes in large amounts and small amounts of iodine were held back. When, however, the bulk of the salt was removed the method worked satisfactorily. Distillation with ferric chloride was also tried and this too failed to show any iodine in the Pomeroy brine.

In the Cleveland brine iodine was not recognized with certainty, though it is possible that by taking a larger portion for the analysis it could be found.

In conclusion it might be stated that substances not given in the tabulated analyses were not looked for.

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